

REMARKS

Firstly, applicants confirm election of Group 1 (method claims 1-9) for examination.

The objection to the drawings is not understood. It is noted that the Examiner has acknowledged receipt of the communication filed November 21st, 2001, and this included drawings. A further copy of the formal drawings is attached. It is noted that these drawings have been amended by the deletion of the box identified at 68 in Figure 7, as this forms no part of the invention and was not identified in the description.

With respect to the request for substitute specification, a substitute specification is provided under 37 CFR 1.125(b). As required, the undersigned hereby confirms that the specification contains no new matter. A marked up copy of the specification is attached, showing the minor changes entered, and it will be understood that these are entirely of a minor, editorial nature, e.g. deletion of unnecessary spaces, duplicate periods and the like.

The Examiner then rejected the claims as being anticipated, or in the alternative, obvious under 35 USC 103, in view of Jacobs et al, Weitman, Marlow or JP 56-119434. These rejections are respectfully traversed for the reasons given below, and in view of the amendments made to the claims.

The Examiner argued that each of these references disclosed spraying water into a relatively warm process gas to produce saturated or nearly saturated conditions. The Examiner then made the allegation that the saturated process gas is subsequently cooled to condense out excess moisture, and further the excess moisture is drained or otherwise eliminated. The Examiner further alleged that in each of these references the process gas is subsequently reheated to obtain a desired final temperature and relative humidity.

This analysis of the prior art is respectfully traversed, and the Examiner is directed to the detailed review of these references below. In many instances, these features are simply not found in the references. Firstly, it is noted that all of these references are concerned generally with air conditioning systems or the like. None of these references is concerned specifically with the problem of providing humidified process gas to a fuel cell stack. Thus, none of these references specifically address the problem of humidifying a fuel gas, such as hydrogen; nor do any of these references address the problem of the very tight requirements required, for fuel cells, in terms of precise control on humidity and temperature. For air conditioning systems, while some

element of control is provided, in general, the volumes of gases involved are many orders of magnitude higher and tolerances on temperature and humidity are much greater, i.e. it is not necessary to have air for air condition spaces maintained within very tight tolerances of humidity and temperature. Also rapid response times are not critical.

Thus, the Weitman reference discloses an apparatus for treating so called contaminated gas, more particularly contaminated air. To this end, it provides a first stage 1 acting as combined heat exchanger and scrubber. To this end, a heat exchange coil or the like 5 is provided, which is stated to be for either transferring heat to or from the air (column 3, lines 62 and 63). The injection means 6 sprays a scrubbing liquid onto the contact surfaces 5, to enhance the vaporization of the injected water while binding impurities entering with the air (column 3, lines 66 to column 4 line 1).

The air then passes over a temperature sensor 12 that controls a control valve 13 to control the supply of heat exchange fluid to the first stage. Corresponding, a sensor 14 controls the supply of heat exchange fluid to heat transfer surfaces 11 in a second stage 2 of the apparatus. Note that the surfaces 11 are intended to be heated, so as to heat the air (column 4, lines 37 and 38).

Consequently, this Weitman proposal lacks many of the elements of the present invention. It provides no equivalent to the separate step (a) of humidifying the process gas stream to the first temperature, and a separate step (b) of the present invention, cooling the process gas stream to second temperature lower than the first temperature to cause condensation of excess moisture. Rather, humidification is done, in an apparently uncontrolled fashion in the first stage. While the second stage 2 may provide some equivalents to heating the gas to a higher temperature, in view of the fact that the absolute humidity of the gas entering the second stage is neither known nor monitored, this proposal provides a system that falls well short of the requirements for precise temperature and humidity control in a fuel cell environment.

The Marlow '382 patent is an old proposal, entitled Psychometrically Controlled Air Conditioning System. As such, this provides a scheme in many ways comparable to that in Weitman. Thus, there is a vaporator 13, and sprays from so-called air washer nozzles 12 are directed at the thin tubes of the evaporator 13. Here, the invention is to cool the air and wash the air. Note that the air downstream of the evaporator 13 is described as "chilled dehumidified air". The air is then reheated at 14, before being delivered back to the conditioned space.

Thus again, there is failure to provide the two separate and distinct steps of humidifying the gas at a first temperature and then cooling the gas to a second, lower temperature, so that the precise, absolute humidity of the gas is known.

The Jacobs et al proposal is concerned with a temperature and humidity control system for an enclosure, such as a museum display case. Thus, it is concerned with a wholly different field from the present invention, and it is submitted that this teaching in no way amounts to analogous art, and that it would not have been considered by a person skilled in the art of fuel cell design, addressing the problem of controlling temperature and humidification levels of fuel cell process gases.

In Jacobs et al, there is provided a generator 2. A fan 16 draws in air from the conditioned space and blows the air down across a water bath 17, to humidify the air. The humidified air then passes under wall 18 and over fins on the cold side of a heat exchanger 19. A solid state heat pump pumps heat to the hot side of the heat exchanger, which is cooled by ambient air delivered by fans 21,22. As indicated, schematically, this is intended to cause water to become supersaturated, so that excess moisture condenses and drips back down into the water bath 17. The air then passes through to a reheater manifold 25 including an electrical heating element 26. The reheated air passes back to the conditioned space.

While there may be some similarities with the present invention, it is first noted, again, that this invention is nowhere concerned with the design of fuel cells. It is submitted that, in view of the status as non-analogous art, it would be in no way obvious to combine this proposal with any proposal concerning fuel cells. Moreover, as it is concerned with conditioning relatively small spaces, there is no reason or basis to consider combining it with art relating to conditioning the space inside buildings.

Moreover, the means by which heat is transferred to the conditioned air, either to cool the air or to heat the air, is quite different from the present invention. Thus, the air is cooled by means of the solid-state heat exchanger 12, and then reheated by an electrical heater 26. In contrast, the present invention uses temperature control circuits, including further heat exchangers, to enable precise control of a heat transfer fluid. The heat transfer fluid then passes through heat exchangers to effect heating or cooling as required, to exact temperatures, i.e. temperatures maintained within desired limits.

Finally, with respect to the Japanese reference 56-119434, this is concerned again with conditioning room air. As such, the air first passes through a water spraying cyclone, then passes through a mist spraying cyclone where it is stated that the air is supersaturated and water is removed. The air then flows through a water drop removal

cyclone 30 and to a temperature controlling cyclone 101, where the air is apparently reheated.

Again, what is missing here is any stage where the air is subject to any specific cooling step, after the air has been humidified with moisture. The assumption in this proposal is that the two, first cyclones 6,20 would cause the water to be supersaturated, and indeed such an effect is claimed. In contrast, what the present invention does is to assume that any humidification step will, likely, not produce complete saturation of the gas, so that the absolute humidity level can never be known with any degree of precision. Accordingly, the present invention then cools the process gas, to a certain temperature so that the exact relative humidity level is then known. Such a technique is nowhere taught in this Japanese reference.

In a fuel cell environment, a fuel cell must be capable of responding rapidly to changes in load on a fuel cell, which in turn can be rapid, large and unpredictable.

During start up and shut down, humidity levels must be controlled to ensure that there is no flooding, particularly on start up and also that the fuel cell is not allowed to dry out. If the fuel cell becomes too dry, then the internal membrane of a proton exchange membrane (PEM) fuel cell can become damaged. Moreover, it is commonly required to provide different relative humidity levels, depending upon current densities, temperature of the fuel cell and other factors. Thus, regulating temperature and humidity of fuel cell process gases represents problems quite different from those addressed in the cited references.

A fuel cell system must be capable of responding rapidly and accurately to abrupt changes in load. Temperature and humidity levels may have to be changed in a matter of minutes or seconds, to new and accurate levels. Such stringent requirements are simply not required or taught in the air conditioning art.

With a view to better distinguishing the invention as claimed in claim 1, the subject matter of claim 3 is, in effect, being introduced into claim 1, with claim 3 being deleted. Thus, claim 1 now calls for the process gas stream to be humidified by the injection of steam.

With respect to claims 3 and 4, the Examiner had further relied upon the disclosure in Allen et al. Allen et al is concerned with art entirely remote from the present invention, namely a Humidifier for Control of Semiconductor Manufacturing Environments. As such, it discloses some unique arrangement including nozzles for injecting steam into airflow in some allegedly controlled manner. The airflow is apparently open and unconstrained, and it is not seen how this is in any way relevant to

a fuel cell system, nor how it could be in any way incorporated into a fuel cell system. Moreover, since this injection is apparently into some unconstrained airflow, it is not seen how this can produce supersaturation as required by claim 4.

In the context of a system for supplying process gases to fuel cell, steam injection provides a number of advantages, which are nowhere taught or suggested in the art. The following advantages can be noted,

- (1) ability to rapidly humidify process gas in a small space and at a high velocity, while avoiding formation of a two-phase mixture;
- (2) process piping can be simpler and space requirements much smaller;
- (3) it gives a low thermal response, and there is no necessity for significant heat transfer from the process gas to water, in the liquid state, to vaporize the water – in fact, high temperature steam can heat the air;
- (4) it enables precise control of humidity;
- (5) the present invention is applicable not just to ambient pressure systems, but to pressurized fuel cell systems, and pressurized systems are nowhere addressed in any of the cited art (pressurized systems can operate, for example, at up to 50 psi gauge);
- (6) Allen et al rely upon the use of a float chamber with a float switch to maintain a stable water level, and in such devices, maintaining a stable water level is critical to producing any consistent level of humidification (see the statements in column 1, lines 25-27 and 35-38 of Allen which acknowledge this problem). Practically, it is impossible with such systems to obtain any uniform level of humidification;
- (7) Allen et al is intended to provide an essentially constant level of humidification, and nowhere addresses the issue of rapidly and dynamically changing demands, e.g. in the fuel cell system, gas flow rates can be switched from 10 liters a minute to 1000 liters per minute in a matter of seconds, with such flow being in a small, one inch diameter duct, and hence requiring small time constants. Additionally, the temperature requirement can be altered by tens of degrees, e.g. from 60 to 80 degrees, in a matter of seconds.
- (8) the present invention controls the temperature of the gas at 2 points, namely when the steam is injected, and when the gas is cooled to condense out excess moisture; optionally, the gas temperature can be controlled at a third temperature when the gas is reheated to give a desired relative humidity;

(9) Allen et al, like many proposals in this art would require humidity to be determined by direct measurement humidity; in contrast to the present invention, humidity can be determined by a temperature measurement, which is simpler, cheaper and more accurate. Humidity sensors are more expensive than a simple thermocouple-based temperature sensor, e.g. humidity sensors can be in the order of \$2000 each. Thus, for two process gas lines, humidity sensors alone can cost \$4000, and such sensors give poor performance and are not very accurate. Moreover, such sensors cannot work with explosive gases such as hydrogen and are not dynamic, as they can take a matter of minutes to respond. Where gas is pressurized, humidity sensors need to be recalibrated for different pressures. With the present invention, humidity can be determined solely from the temperatures at the different locations, avoiding expensive humidity sensors and giving a rapid, dynamic measurement of relative humidity/

The Examiner's argument that it would be obvious to combine Allen et al with the other references is respectfully traversed. Firstly, as noted above, the argument that original claim 1 was not obvious in view of the various cited references is again repeated. None of the references provide a system suitable for humidifying a process gas, in a small space, e.g. in process piping, to give a rapid, dynamic response in humidity requirements, and a gas flow whose temperature and flow conditions can be changing rapidly.

With respect to the argument that it would be obvious to incorporate the teaching of Allen et al, the Examiner is respectfully referred to MPEP 2143.01 where it is noted that obviousness can only be established "where there is some teaching, suggestion, or motivation to do so found either explicitly or implicitly in the references themselves or in the knowledge generally available to one of ordinary skill in the art".

In the present case, there is absolutely no reason or basis to consider combining the references in the manner suggested by the Examiner. The references are all concerned with humidifying large spaces, e.g. buildings and the like, except for the Jacobs et al patent which is concerned with museum display cases. Providing the complexity of steam injection is totally unwarranted in any such system, and it is not even seen how steam injection could be applied. For example, in the case of equipment intended to air condition air for living spaces, the volumes of air are large, and providing steam injection would be exceedingly complex and costly. Accordingly, there is simply no reason or basis to consider such a modification.

More importantly, none of these references are concerned with humidification of air, where, short time constants and rapid response are required. In all cases, it is usually just required that the relevant space or volume be maintained at a desired level

of temperature and humidity. If any change of humidity is set, then the issue of how long it takes the new setting to be achieved is not really a factor. Moreover, the degree of precision required in such installations is generally not large. Accordingly, these references give little assistance to a fuel cell designer seeking to provide a system having rapid response and accurate and repeatable levels of temperature and humidity.

To deal with the more specific points raised by the Examiner, the Examiner argued that claims 7-9 teach controlling temperature and relative humidity to desired set point, and argued that no particular significance is attached to the claimed figures. It is noted the Examiner has not cited any specific reference in detailing similar temperature ranges. More significantly, in view of the fact that the prior art generally is concerned with conditioning air for living spaces, such temperature ranges are nowhere taught or suggested in the art.

With respect to claim 5, the Examiner had relied upon the disclosure in DuBose et al. The Examiner alleged that DuBose teaches a need to control temperature humidity of the oxygen supplied to a fuel cell, and further that it would therefore be obvious to use any of the prior art systems to condition an oxidant (typically air) to a fuel cell.

The passage cited by the Examiner merely sets out a desideratum or problem, without providing any solution.

The system of DuBose provides for humidifying air as shown in Figure 2. This is wholly different from anything proposed by the present invention. This includes a so-called adiabatic quench means 36. This introduces a fine mist of water whose main function, apparently, is to reduce temperature and provide some humidification to the air. An enthalpy wheel 46 serves to exchange heat and moisture between outgoing and incoming air streams. As the outgoing air stream is at an elevated temperature, the quenching mist is provided to ensure that the incoming air stream is not heated excessively.

It will be understood that this arrangement is wholly different from the present invention, and, importantly, is wholly from all the art cited by the Examiner. It is not seen how it is any way obvious to combine any of the cited systems for conditioning conventional room air with this arrangement of DuBose. Moreover, since DuBose already includes some humidification scheme, there is absolutely no reason or basis to consider any modification to it.

Additionally, the present invention is not limited to humidification of air. It is concerned with humidification of any process gas stream, including for example

hydrogen. The parts of DuBose cited by the Examiner and all the prior art are concerned with humidifying an air stream, and nowhere address the necessary humidification of a hydrogen stream.

The Examiner further cited column 5, lines 41-45 of DuBose, but these merely give desired operating conditions, and this passage is of no assistance in defining the method now claimed.

With respect to claims 5 and 6, the Examiner further relied upon Gross, for disclosing a line heater. Again, Gross is concerned with a wholly different art area, namely the fabrication of LSI and VLSI semiconductor devices, which rely upon chlorine based chemistry. For various etch steps, a number of gases are used, which are often, apparently, termed "liquid source gases". Thus, liquid is stored in a container and a vacuum source is applied, to pull vapor from the top of the liquid. Gross is concerned with the problem that such vapor may, inadvertently condense at unwanted points in a supply line. Accordingly, a line heater is provided to ensure that this does not occur. Details of the heater are shown in Figure 3, and it can be seen that this includes an outer annular chamber through which heated fluid such as water is pumped to maintain the temperature.

Thus, it is submitted that this is clearly non-analogous art, and teaches nothing about the problems of supplying properly humidified process gases to fuel cells. As such, there is no reason or basis in this art for considering combining this proposal with other prior patents. Moreover, the technique for heating the line is entirely different from that proposed by the present invention.

The newly submitted claims 19-33 are directed to other aspects of the invention previously disclosed but not fully claimed. Thus, claims 19 and 20 detail aspects of the heating circuits, shown in Figure 1, in a form dependent from earlier claims.

Claim 21 is then an independent method claim, again directed to this aspect of the invention. It is submitted that this aspect of the invention is clearly patentable. None of the art cited by the Examiner shows any such technique for controlling temperature of a heat exchanger. Thus, the present invention provides two temperature control circuits, each including heat exchangers in the process gas stream path. Through each of these heat exchangers, heat transfer fluid flows, which is subject to separate temperature adjustment by a heater and/or a further heat exchanger.

Such an arrangement has numerous advantages, and is directed to the particular requirements of controlling temperature and humidity of fuel cell process gas streams. Thus, in fuel cells, it is required to have very rapid response times, in the order of a

couple of minutes. It will be understood that such a requirement is nowhere required for air conditioning equipment, which typically is simply required to maintain relatively constant values, and much slower response times are quite acceptable.

Claim 26 is directed to the feature of relying upon the temperature at different points to determine humidity, rather than measurement of relative humidity. As mentioned, this enables rapid, inexpensive and dynamic measurement of humidity. Such a technique is nowhere taught in the cited art. No new matter has been added, and this aspect of the invention is disclosed in many places in the specification and drawings. For example, the description of Figure 1 makes it clear that the temperature of the process gas steam is controlled and known, so that the relative humidity level at the outlet is known.

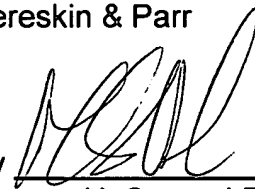
New claim 27 has been added which is essentially directed to a combination of former claim 1 and claim 5. Thus, this claim now calls for an additional step (e) in which the humidified process gas is supplied to a fuel cell and the temperature of the process gas stream is maintained until it reaches a fuel cell stack. Accordingly, it is submitted that this claim is clearly distinguished from the cited art. None of the art is concerned with humidification of a fuel cell, and therefore, nowhere addresses the issue of maintaining a process gas stream temperature until it reaches a fuel cell. It is to be understood that, in the fuel cell art, the process gas stream may be flowing through a relatively small conduit, e.g. one inch in diameter or less, where there is a relatively large surface area, so that the problem of heat transfer from the conduit is significant. In contrast, in the air conditioning art, this is simply not a factor.

Claim 28 depends from claim 27 and essentially corresponds to former claim 2.

Respectfully submitted,

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

In the claims:

Claims 1 and 4 have been amended as follows:

1. A method of humidifying a process gas stream, the method comprising:
 - (a) humidifying injecting steam into the process gas stream, so as to humidify the process gas stream at a first temperature and so as to provide the process gas stream with excess humidity;
 - (b) cooling the process gas stream at a second temperature, lower than the first temperature, to cause condensation of excess moisture;
 - (c) removing excess condensed moisture from the process gas stream;and
 - (d) delivering the process gas stream at a known temperature, whereby the absolute humidity level in the process gas stream is determined from the maximum relative humidity at the second temperature.
4. A method as claimed in claim 3 2, which includes injecting steam into the gas stream in an amount sufficient to supersaturate the process gas stream.

19. (new) A method as claimed in claim 1, 3 or 4 wherein step (b) comprises passing the process gas stream through a first heat exchanger, and passing a heat transfer fluid through the first heat exchanger to cool the process gas stream to the second

temperature, and step (d) comprises passing the process gas stream through a second heat exchanger and passing a second heat transfer fluid through the second heat exchanger to heat the process gas stream to the third temperature.

20. (new) A method as claimed in claim 19, which includes passing the first heat transfer fluid through a first temperature control circuit, including a first heater and a third heat exchanger, for controlling the temperature of the first heat transfer fluid, and passing the second heat transfer fluid through a second temperature control circuit, including a second heater and a fourth heat exchanger, for controlling the temperature of the second heat transfer fluid.

21. (new) A method of humidifying a process gas stream, the method comprising:

(a) humidifying the process gas stream at a first temperature so as to provide the process gas stream with excess humidity;

(b) cooling the process gas stream at a second temperature, lower than the first temperature, to cause condensation of excess moisture;

(c) removing excess condensed moisture from the process gas stream;

(d) delivering the process gas stream at a known, third temperature, whereby the absolute humidity in the process gas stream is determined from the maximum relative humidity at the second temperature;

wherein step (b) includes passing the process gas stream through a first heat exchanger, passing a first heat transfer fluid through the first heat exchanger to cool the process gas stream to the second temperature, and passing the first heat transfer fluid through a first temperature control circuit including at least a third heat exchanger, for controlling the temperature of the first heat transfer fluid.

22. (new) A method as claimed in claim 21, which includes providing, in the first heat transfer circuit, a first heater for heating the first heat transfer fluid.

23. (new) A method as claimed in claim 21, which includes, prior to step (d) heating the process gas stream in a second heat exchanger to the third temperature, whereby the third temperature is greater than the second temperature, and passing a second heat transfer fluid through the second heat exchanger to heat the process gas stream.

24. (new) A method as claimed in claim 23, which includes passing the second heat transfer fluid through a second temperature control circuit including a second heater and a fourth heat exchanger, for controlling the temperature of the second heat transfer fluid.

25. (new) A method as claimed in claim 24, which includes maintaining the third temperature of the process gas stream, by delivering the process gas stream through a supply line and providing a heating element extending along the supply line.

26. (new) A method as claimed in claim 2, which includes determining the relative humidity of the process gas stream at the third temperature solely from measured values of the second and third temperatures, and setting the second and third temperatures, to obtain a desired level of relative humidity in the process gas stream.

27. (new) A method of humidifying a process gas stream, the method comprising:

_____ (a) humidifying the process gas stream at a first temperature so as to provide the process gas stream with excess humidity;

_____ (b) cooling the process gas stream at a second temperature, lower than the first temperature, to cause condensation of excess moisture;

_____ (c) removing excess condensed moisture from the process gas stream; and

(d) delivering the process gas stream at a known, third temperature, whereby the absolute humidity level in the process gas stream is determined from the maximum relative humidity at the second temperature; and

(e) supplying the humidified process gas stream at the third temperature to a fuel cell, and maintaining the third temperature of the process gas stream from step (d) at the third temperature, until the process gas stream reaches the inlet of a fuel cell.

28. (new) A method as claimed in claim 27, wherein step (d) includes heating the process gas stream to a third temperature greater than the second temperature.